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Temperature–mortality relationship in four subtropical Chinese cities: A time-series study using a distributed lag non-linear model

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HIGHLIGHTS

- U-shaped relationship between temperature and mortality was found.
- Both low and high temperatures were associated with increased mortality.
- The cold effect was more durable and pronounced than the hot effect.
- The cold and hot effects were greater among the elderly.

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ABSTRACT

Background: Numerous studies have reported the association between ambient temperature and mortality. However, few multicity studies have been conducted in subtropical regions in developing countries. The present study assessed the health effects of temperature on mortality in four subtropical cities of China.
Methods: We used "double threshold-natural cubic spline" distributed lag non-linear model (DLNM) to investigate the cold and hot effects on mortality at different lags in four subtropical cities. Then we conducted a meta-analysis to estimate the overall cold and hot effects on mortality at different lag days.
Results: A U-shaped relationship between temperature and mortality was found in the four cities. Cold effect was delayed and persisted for about 27 days, whereas hot effect was acute and lasted for 3 days. In Changsha, Kunming, Guangzhou and Zhuhai, a 1 °C decrease of temperature under the low threshold was associated with a lag0–27 cumulative relative risk (RR) of 1.061 (95% confidence interval (CI): 1.023–1.099), 1.044 (95% CI: 1.033–1.056), 1.096 (95% CI: 1.075–1.117) and 1.111 (95% CI: 1.078–1.145) for total mortality, respectively. And RR for 1 °C increase of temperature above the hot threshold at the lag0 was 1.020 (95% CI: 1.003–1.037), 1.017 (95% CI: 1.004–1.030), 1.029 (95% CI: 1.020–1.039) and 1.023 (95% CI: 1.004–1.042), respectively. The cold and hot effects were greater among the elderly in Changsha, Guangzhou and Zhuhai. Meta analysis showed that the hot effect decreased gradually with lag days, with the greatest effect at current day (RR = 1.023, 95% CI: 1.015–1.031); while the cumulative cold effect increased gradually with lag days, with the highest effect at lag0–27 (RR = 1.076, 95% CI: 1.046–1.107).
Conclusion: Both low and high temperatures were associated with increased mortality in the four subtropical Chinese cities, and cold effect was more durable and pronounced than hot effect.

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) has projected that the global mean temperature will continue to rise by 1.1–6.4 °C in the 21st century (IPCC, 2007). In the context of global warming, the mean temperature of China is also projected to rise, and extreme weather events (heat waves or cold spells) are likely to occur more frequently and intensively in the next decades (Ding et al., 2006).

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Over the past two decades, interest in investigating the association between temperature and mortality has been increasing as a response to climate change caused by increased greenhouse gas emission. These previous studies have generally reported a U, V or J-shaped relationship between ambient temperature and mortality, which means that the mortality is usually lowest around a certain temperature and higher at lower or higher temperatures (Armstrong, 2006; Huynen et al., 2001; Alberdi et al., 1998; O'Neill et al., 2003; Curriero et al., 2002; Kan et al., 2007; Laaidi et al., 2006). In order to further estimate the effects of low or high temperature on mortality, previous studies usually divided the temperature–mortality curve into three linear sections with hot and cold thresholds using a linear-threshold model (Armstrong, 2006), and the middle section was constrained to a zero slope (Yu et al., 2011). It is well known that the low and high temperature effects can persist for a few days (Anderson and Bell, 2009). Many studies found that exposure to temperature of the current day may impact the mortality of several days later (Ha et al., 2011; Sugimoto et al., 2012). Recently, a new model, namely distributed lag non-linear model, has been developed to simultaneously investigate the delayed effects and the non-linear exposure–response relationship (Gasparrini et al., 2010).

The health impacts of climate change are likely to be more serious in developing countries (IPCC, 2007). However, most of the previous studies were conducted in developed countries, and fewer studies have been carried out in developing countries. China is not an exception. In recent years, although there have been a few studies exploring the temperature–mortality relationship in a single city in China (Kan et al., 2007; Yan et al., 2011; Si et al., 2011), these single-city studies used different methods and parameter specifications, and most of them failed to consider the delayed effects of temperature on mortality and were therefore difficult to compare. Moreover, it is evident that few multisided studies have been carried out in subtropical Chinese cities (Lin et al., 2011). Therefore, multi-city studies conducted in subtropical regions to elucidate the temperature–mortality relationship are necessary and will be more informative.

In the present study, we conducted a time-series analysis by integrating the meteorological data, mortality data and air pollution data from four subtropical cities (Changsha, Kunming, Guangzhou and Zhuhai as shown in Fig. 1) in southern China. The distributed lag non-linear model (DLNM) was firstly applied to estimate the effects of temperature on mortality in each city, and then a meta-analysis was used to combine the results. The findings from this study will provide useful information for Chinese policy makers to better understand the health effects of temperature in subtropical regions.

2. Materials and methods

2.1. Study sites

We selected four subtropical cities (Changsha, Kunming, Guangzhou and Zhuhai) with different characteristics in southern China (Fig. 1). Changsha, a major heavy-industry city, has a distinct four seasons with cold winter and hot summer. Guangzhou is a subtropical monsoon climate, which has more warm weather in winter. Zhuhai, which is a coastal city near Guangzhou, exhibits a similar climate with Guangzhou. Kunming has temperate climates in China, characterized by short, cool winter with mild days and long warm summer but much cooler than Guangzhou and Zhuhai. Due to the data availability, we used data from one district from Changsha city (Tianxin District) and two districts from Guangzhou city (Yuexiu and Liwan Districts).

The four cities have their own socio-economic characteristics. Changsha is an important regional centre in the central China; Kunming is one of tourism and commercial cities in the western China; Guangzhou is the largest metropolitan city in Southern China and Zhuhai is an important tourism city in the Pearl River Delta. In 2009, the populations of Changsha (Tianxin District), Kunming, Guangzhou (Yuexiu and Liwan Districts) and Zhuhai were 0.41 million, 6.28 million 1.87 million and 1.49 million, respectively. Gross Regional Domestic Product (GDP) for the four cities was 3.42, 180.87, 200.49 and 103.77 billion CNY, respectively, and per capita annual disposable income for the four cities was 18.9, 16.5, 53.1 and 22.6 thousand CNY, respectively (National Bureau of statistics of China, 2009).

2.2. Data collection

Meteorological data of Changsha and Kunming during 2006–2009 and Guangzhou and Zhuhai during 2006–2010, including daily mean

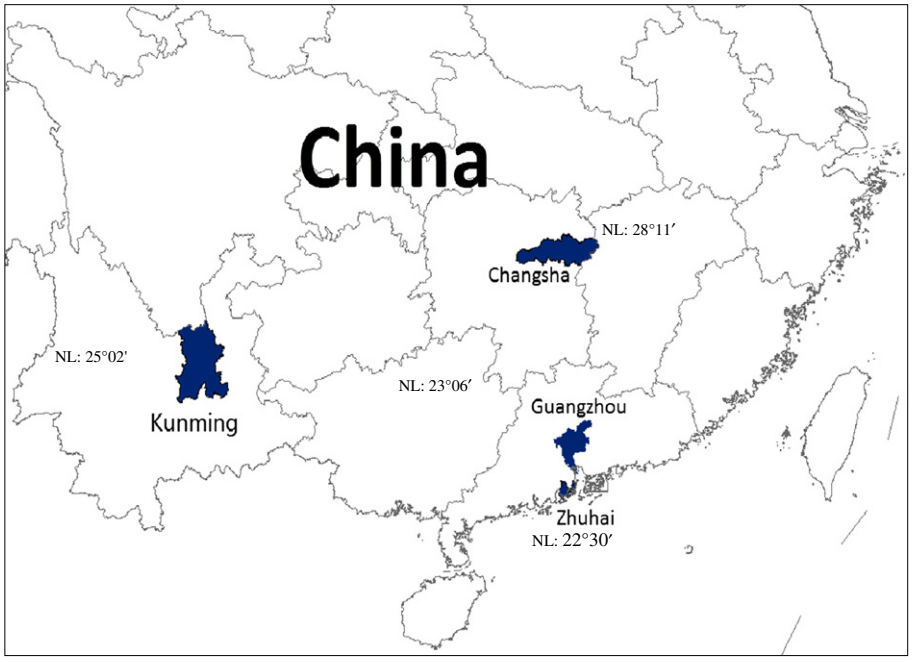

Fig. 1. Geographical distribution of study areas in China.